PRELIMINARY STAFF DRAFT

COMPARING THE EFFECTS OF TWO ACCELERATED VEHICLE RETIREMENT PROGRAMS USING A BEHAVIORALLY-BASED VEHICLE CHOICE MODEL

TARGETING TEN-YEAR AND OLDER VS. TARGETING TWENTY-YEAR AND OLDER PERSONAL LIGHT-DUTY VEHICLES

Includes a Supplement

Chris Kavalec
Winardi Setiawan
Demand Analysis Office
California Energy Commission
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LEGAL NOTICE

LEGISLATIVE BACKGROUND

Light-duty vehicle accelerated retirement programs have been implemented on a short term basis several times in California and elsewhere. The programs' objective has been to remove or scrap older light-duty vehicles that are responsible for high levels of air pollution combustion emissions. Such a program was adopted as a control measure in the Air Resources Board's *The California State Implementation Plan for Ozone* on November 15, 1994. Measure M-1's goal is to reduce reactive organic gases (ROG) and oxides of nitrogen (NOx) emissions from light duty vehicles in the South Coast Air Basin by implementing an old vehicle retirement program through to 2010. This control measure had the force of law added when Senate Bill No. 501 was approved by the Governor in 1995.

The bill requires the Air Resources Board to establish a statewide privately operated program, to be overseen by a state agency designated by the Governor, to generate emission reduction credits through the retirement of or disposal of high-emitting light-duty vehicles, as provided in Measure M-1. The Air Resources Board is now in the process of designing a two year pilot implementation program to assess the costs and short-term and long-term emission benefits of the scrappage program.

As provided in various provisions of Senate Bill 1214 (enacted in October 1991), the California Energy Commission, in consultation with the Air Resources Board and others, is required to evaluate various programs which might be used to reduce transportation environmental impacts and energy consumption. Vehicle retirement programs are potentially one such option. Using the available tools at its disposal, the Commission staff's evaluation of retirement programs is most timely, in that we can work toward meeting our legislative mandate and potentially at the same time assist the Air Resources Board and others in implementing a large-scale vehicle retirement program, identifying potential problem areas, and assessing potential program impacts.

EXECUTIVE SUMMARY

Efforts in California to reduce air pollution from mobile sources have recently begun to include programs offering a bounty for the voluntary retirement of older, more polluting light-duty vehicles. Such programs have been attempted on a small scale by private companies such as UNOCAL and by various local governments. Results from these programs have been encouraging enough so that a large-scale accelerated vehicle retirement program (AVRP) has been proposed in the State Implementation Plan (SIP) for the South Coast region beginning in 1999 and continuing through 2010.

This paper presents a methodology for examining large-scale vehicle retirement programs such as that proposed for the South Coast and presents the results of two simulations of light-duty vehicle accelerated vehicle retirement programs. This work, part of the Commission staff efforts in support of Senate Bill 1214 to evaluate various programs which might be used to reduce environmental and economic costs related to transportation, offers initial estimates of the impacts of different program design options and the overall effects of a large-scale vehicle retirement program.

Staff analysis of AVRPs uses the California Conventional and Alternative Fuel Response Simulator (CALCARS), the California Energy Commission's behavioral light-duty vehicle choice/demand/usage model, to analyze the retirement decision at the individual household level. Retirement programs affect the satisfaction, or *utility*, associated with owning a targeted vehicle by offering a bounty higher than the current market price of the vehicle and/or by reducing the costs associated with selling the vehicle.

This methodology has distinct advantages over those used in past studies. First, the model can predict the number of vehicles by type and model year retired with a given bounty. Second, there is no need for simplifying assumptions for replacement vehicle miles traveled (VMT). Third, no assumptions need to be made regarding the amount of time a retired vehicle would otherwise have stayed on the road--the remaining life of the vehicle is endogenous in the model. Finally, the effect of an AVRP on used vehicle prices and consumer welfare can be estimated.

A study by Sierra Research (1995) showed that the emission reductions of reactive organic gases (ROG) and oxides of nitrogen (NOx) required by the State Implementation Plan (SIP) for light-duty vehicles (M-1) could be met by retiring around 75,000 vehicles annually from 1999-2010, assuming these vehicles were high emitters[1]. However, targeting high emitters, along with adding costs to any AVRP, may not be an effective strategy given the "moral hazard" that may be created.[2] Offering a bounty for such

[1] A high emitter is usually defined to be from twice to six times as high (depending on the pollutant) as the Federal Testing Procedure (FTP) standards for a given model year.

[2] Moral hazard is usually defined in the context of insurance, where the existence of that insurance removes at least some of the incentive to exercise care.

vehicles may give an incentive to owners of vehicles that are not high emitters to tamper with the vehicle so that it becomes eligible for the bounty. If this is the case, emission reduction estimates from actual scrapped vehicles would be overstated. In addition, enhanced inspection and maintenance programs will specifically target high emitters, and would be expected to reduce their number even without the existence of an AVRP.

In this study, retired vehicles are assumed to pollute at a level based on California Air Resources Board assumptions for a given model year, using the emission inventory models EMFAC(7F)/ BURDEN(7F). For example, if 20 percent of vehicles are assumed to be high emitters in some model year, the same percentage will apply to retired vehicles (if any) for that model year when emission reductions are estimated. Two scenarios are simulated: a program targeting ten-year and older light-duty vehicles (10+ program) and one targeting twenty-year and older vehicles (20+ program). The Sierra study examined programs targeting eight-year and older and twelve-year and older vehicles, so the 10+ program could be considered an "average" of these two, and is designed to represent approximately what programs targeting vehicles in this age range would be expected to achieve. Although the emission reductions from the 10+ program are not directly comparable to those from the Sierra study (as not all retired vehicles are assumed to be high emitters), it does provide estimates of the annual bounties which might be required to retire 75,000 vehicles.

The main results from this research are listed below.

(1) Simulation of the 10+ program provides evidence that the $1,000 per vehicle bounty assumed in the Sierra study may indeed be sufficient for around 75,000 retirements. However, without the assumption of all scrapped vehicle being high emitters, this program would meet the SIP requirements in only three of the forecast years.

(2) The 20+ program as simulated shows that targeting even older vehicles may be a significantly more cost effective way to reduce ROG+NOx. The results of the simulation show that while the bounty required for retirement of a given number of vehicles would be as much as $500 higher than in the 10+ program, the number of retirements required for a given reduction in emissions would be so much lower (around 37,500 in most years) that the result is higher (25 to 30 percent) cost effectiveness. Indeed, the simulated 20+ program is projected to meet the M-1 SIP requirements for ROG+NOx in all years except the first (1999), even though the projected total cost of the 20+ program is lower.

(3) As both simulated programs would reduce the average age of vehicles, and over 80 percent of retired vehicles would be replaced, total VMT increases for the South Coast in each case (the maximum projected increase is 0.64 percent in the 20+ program in 2010 -- see Tables 8 and 12). Somewhat surprisingly, total gasoline use is projected to rise in each year of the programs as well (the maximum would be 0.80 percent in the 10+ program in 2007 -- see Tables 8 and 12). In the

20+ program, it appears that the fuel demand increase resulting from more driving due to reduced average vehicle age would overwhelm the demand decrease from higher fuel economy due to that reduced age. In the 10+ program, the fuel demand increase would be augmented by a reduction in average fuel economy, as many of the low-value 10-20 year old vehicles that are retired (e.g., mini and subcompact cars) would have higher fuel efficiency than many of the vehicles that replace them.

(4) In both programs, the loss in welfare as a result of the bounty driving up prices for targeted vehicles is projected to be greatest for the lowest income households. The effects should be relatively minor however: the maximum annual loss over 1999-2010 would be around $2 per lowest income household (see Table 15).

(5) The results described above assume no price effects on other used vehicles as a result of large-scale retirement. If vehicle retirement were to lead to an increase in the prices of other used vehicles, fewer vehicles would be replaced for a given number of retirements. Therefore, ignoring price effects means that projected emission reductions may be understated, all else equal, and the projected effects on VMT and fuel use overstated. In addition, adverse welfare impacts would likely be understated, especially for low income households. For this reason, including price effects would appear to increase the appeal of the 20+ program, as fewer vehicle retirements compared to the 10+ program would mean less effect on the prices of other used cars.

INTRODUCTION

Older vehicles typically produce a disproportionate share of vehicle emissions. For example, cars at least 10 years old accounted for 51 percent of hydrocarbon emissions while contributing less than 18 percent of auto vehicle miles traveled (VMT) in the U.S. in 1991.[3] For this reason, accelerated vehicle retirement programs (AVRPs) have received increased attention as a policy option. Beginning in 1990, scrappage programs have been attempted on a small scale by private companies such as Union Oil and by various local and state governments.

AVRPs are only one of many possible strategies for reducing vehicle emissions of hydrocarbons and nitrogen oxides. One aspect that makes an AVRP particularly appealing is that it may be relatively inexpensive compared to other measures. Of course, the effectiveness of an AVRP would depend on the remaining life of the targeted vehicles as well as on how the travel demand that had been met by the retired vehicles is replaced. AVRPs also have the advantage of relying on market forces (and they are voluntary) rather than on "command and control" directives.

[3] Phil Patterson, Office of Transportation Systems, U.S. Department of Energy.

On the other hand, AVRPs may have disadvantages. First, an AVRP may have adverse effects on low-income households by significantly affecting the price of the lowest cost vehicles.[4] In addition, used car prices in general may be affected as the total supply of these vehicles is reduced. The significance of these effects would depend on the number of vehicles retired and the duration of the program.

A program that reduces the average age of light-duty vehicles in a given area may have a positive effect on total average fuel economy. On the other hand, the higher average mpg level and lower average vehicle age may mean more total VMT. External costs (aside form those caused by tailpipe pollution) related to driving *per se*, such as congestion and noise costs, would then rise.

The programs implemented thus far have been of limited duration and served as demonstration projects. General Motors and the Environmental Defense Fund have designed a large scale, long-term AVRP but no implemented programs have been based on this proposal. Other states considering scrappage programs include Connecticut, Florida, Kentucky, New Jersey, Ohio, Texas, and Virginia.

The California State Implementation Plan (SIP), adopted in 1995, calls for a large-scale AVRP in the Los Angeles region beginning in 1999. Although the specific guidelines for the program are yet to be developed, the plan calls for enough vehicles (up to 75,000 per year) to be scrapped under the M-1 measure so that the sum of reactive organic gases (ROG) and nitrogen oxides (NOx) would be reduced by at least the amounts, in tons per day, shown in Table 1.

Table 1: M-1 SIP Emission Reductions

Year	Tons per Day (ROG+NOx)
1999-2001	9
2002-2004	14
2005-2006	20
2007-2009	22
2010	25

This report focuses on the program planned for the Los Angeles region, and provides insight, through simulations, into two scenarios: an AVRP targeting ten-year and older light-duty vehicles (10+ program) and a program that concentrates on twenty-year and older vehicles (20+ program). The scenarios are simulated using the California Conventional and Alternative Fuel Response Simulator (CALCARS), the California

[4] In effect, an AVRP creates a *price floor* for eligible vehicles. A buyer interested in such a vehicle would have to pay at least the amount of the bounty to acquire it.

Energy Commission's personal light-duty vehicle demand forecasting model (California Energy Commission, 1996).

The first program is simulated assuming that roughly 75,000 vehicles would be retired annually from 1999-2010, as in a study by Sierra Research (1995). In each year, CALCARS is run until the bounty offered in the simulation yields roughly 75,000 retirements. This analysis tests the assumption made in the Sierra study that a bounty of $1,000 per vehicle (including administrative costs) would be sufficient for the scrapping of 75,000 vehicles. The second program simulation suggests that there may be a significantly more cost-effective way of reaching the M-1 SIP requirements. The projected effects of the programs on fuel use, fuel efficiency, VMT, and welfare in the South Coast are also presented.

This report is organized as follows. Section I presents the staff approach to AVRP analysis and how such a program is modeled using CALCARS. Section II presents the results of two simulations, and Section III provides concluding comments. The appendix provides a literature survey on the analysis of vehicle retirement programs.

I. STAFF APPROACH TO AVRP ANALYSIS

The Commission's California Conventional and Alternative Fuel Response Simulator (CALCARS) allows a more comprehensive analysis of a large-scale AVRP than has been attempted so far. CALCARS simulates the ownership, use, and transactions (replacement, addition, or disposal) of all personal cars and light-duty trucks in a given geographic region for up to 41 model years (1970-2010)[5] and 14 size classes (listed in Table 2). CALCARS, which simulates vehicle ownership decisions at a household level, offers a means of determining what types of vehicles (if any) would be chosen as replacements for those that have been retired as well as the mileage by these replacements.

[5] In the base year (1994), 25 vintages are available. The number of vintage choices increases throughout the forecast period until 41 are available in 2010. 1970 is the earliest model year where sufficient data for vehicle characteristics is available.

Table 2: CALCARS Size Classes

Class	Description	Example
1	Mini Car	Chevrolet Chevette
2	Subcompact Car	Geo Prizm
3	Compact Car	Nissan Maxima
4	Midsize Car	Ford Taurus
5	Large Car	Chevrolet Caprice
6	Luxury Car	BMW 325i
7	Sports Car	Mazda RX-7
8	Compact Pickup	Ford Ranger
9	Standard Pickup	Ford F-150
10	Compact Van	Plymouth Grand Voyager
11	Standard Van	Dodge Ram Van
12	Compact Sport Utility	Nissan Pathfinder
13	Standard Sport Utility	GMC Jimmy
14	Mini Sport Utility	Suzuki Samurai

Therefore, CALCARS can not only estimate the number and types of vehicles retired in response to a given offer price, but can also estimate the effect of an AVRP on total VMT and fuel use by personal vehicles in a given geographic area. This methodology should give a much better estimate of the effect of an AVRP on total emissions compared to past studies, for two reasons. First, if a scrapped vehicle is replaced, CALCARS assigns a probability to each possible replacement at a household level and then projects VMT, in each case using vehicle- and household-specific characteristics (e.g., vehicle age, household income). Thus there is no need for simplistic assumptions for replacement VMT (e.g., the Sierra Research 1995 study assumed fleet-average VMT by the replacement vehicle). Second, no assumptions need to be made regarding the amount of time a retired vehicle would otherwise have stayed on the road--the remaining life of the vehicle is endogenous in the model. Estimating emissions reductions due to an AVRP requires only a comparison of a "base" forecast (no AVRP) and a forecast with the AVRP included.

Given that many retired vehicles would be replaced by other used cars and trucks, a fixed stock of non-targeted[6] used vehicles in a given time period and region would mean that the prices of these vehicles would rise due to the increase in demand. On the other hand, the price increase may be offset to some degree by the availability of vehicles on used car lots and used vehicles outside of the region. In other words, the amount that used vehicle prices would rise would depend on the extent that replacement vehicles are brought in from outside of the region and the level of the existing inventory held by used car dealers in the area.

With this in mind, it is possible to define a spectrum with respect to the effects of an AVRP: a *fixed supply* case at one end, where the stock of used vehicles (minus those retired) remains constant and prices increase, and an *unlimited supply* case at the other, where the availability of used vehicles outside of the region or in lots completely offsets any price increase. In the first case, the number of new vehicles would rise, while the stock of used vehicles would decrease by the number of retirements. In the second case, the number of both new and non-targeted used vehicles would increase. The simulations concentrate on the unlimited supply case, but offer some insights for cases in which used car supply is not supplemented by outside sources, so that prices rise.

Vehicle emissions reductions from the simulated AVRPs in this study were estimated using emission inventory models, EMFAC(7F)/BURDEN(7F), developed by the California Air Resources Board (CARB). The EMFAC model computes fleet composite emission factors for each class by weighing each model year contribution while BURDEN uses these factors and county-specific travel activity data to produce emission inventories for summer or winter season. An average day emission for each pollutant is calculated by weighing the different season inventories. The CARB models have been adjusted so that the VMT and fleet composition by model-year projected by CALCARS can be input.

Modeling the Retirement Decision

In CALCARS, households decide in each year whether their currently held vehicle(s) will be kept for another period (year) or will be replaced, based on the *utility* associated with all possible choices, which depends on the characteristics of both the vehicle (e.g., performance, operating cost) and the household (e.g., income, size) as well as the *disutility* (i.e., transaction costs) associated with replacing a currently held vehicle. Households can also dispose of a current vehicle without replacement or add to their current stock.

One way that an accelerated vehicle retirement program can induce vehicle retirement is by making targeted vehicles less appealing to own. In other words, an AVRP can increase

[6] In this analysis, "non-targeted" refers both to vehicles that are not eligible for the retirement bounty and those with a high enough market value that it would likely not be offered for scrappage.

the *opportunity holding cost* of a targeted vehicle. Holding cost refers to what is given up by vehicle ownership *per se* in a particular year--costs related to operating the vehicle, such as fuel, repair, and maintenance, are not included. With no AVRP, holding cost is simply the foregone interest on the resale or market value of the vehicle.[7] Given a real rate of interest r, if an AVRP offers a bounty B that is higher than the market value of a targeted vehicle in year t, MV_t, holding cost would increase by

$$\textbf{(1)}\ r(B\text{-}MV_t),$$

assuming that the bounty will continue to be available next period. If the AVRP is one-year-only or in its final year, holding cost would increase by

$$\textbf{(2)}\ r(B\text{-}MV_t) + (B\text{-}MV_t).$$

In this case, the owner of a targeted vehicle stands to lose not only added foregone interest by not retiring the vehicle in the current year, but also the full amount of the difference between the bounty and current market value--this premium will no longer be available next year. Thus a one-year-only program offers a much higher inducement to retire than a multi-year program; for example, it can be seen from (1) and (2) that the effect on holding cost is eleven times higher in the one-year-only case if the real rate of interest is ten percent.

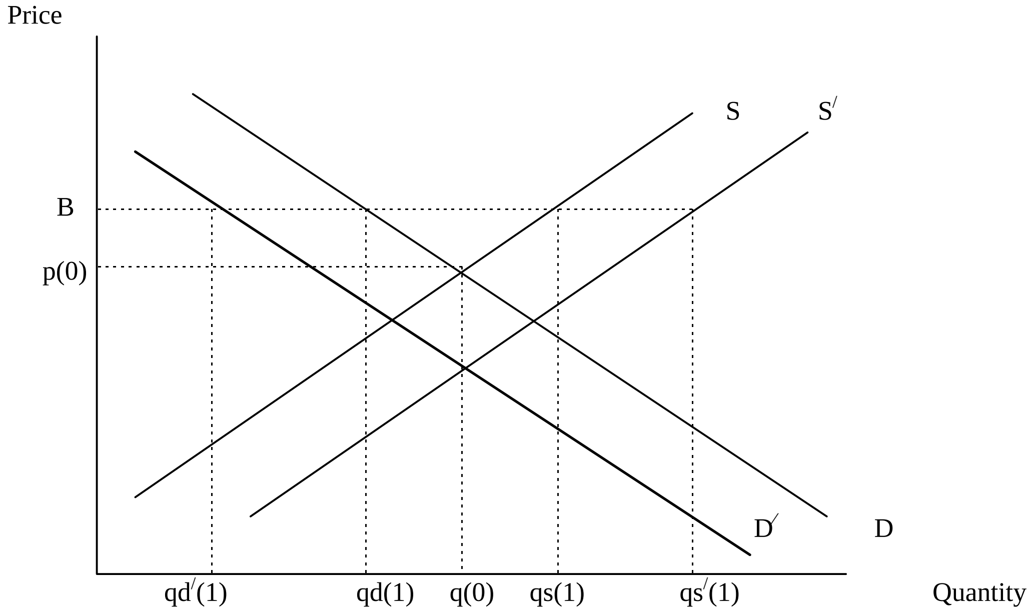
The second incentive that an AVRP can provide to retire a targeted vehicle is a reduction in transactions costs associated with selling the vehicle. For example, an owner could now sell a targeted vehicle without paying for (as currently required by California law) a smog certification, along with any repair costs if the vehicle did not initially pass the smog check. Other costs, such as fix-up, advertising, and time spent negotiating would also be reduced or eliminated.

Figure 1 shows the effect of a multi-year AVRP on the market for a targeted vehicle when the bounty is set above the market price, assuming the program continues into the next period. The market equilibrium before the AVRP, where supply (S) equals demand (D), gives a market price of $p(0)$ and a quantity sold of $q(0)$. After the AVRP, offering a bounty B, is in place, there is now a "price floor" in the market--it is not likely that any household would be willing to sell a targeted vehicle for less than the bounty. Through the effect on holding cost of these vehicles, the quantity offered for sale would rise to $qs(1)$ and private demand would drop to $qd(1)$. If there were no other effect due to the

[7] Note that vehicle depreciation is not included here. A multi-year AVRP may create an incentive to keep a targeted vehicle longer since the vehicle's resale value does not decrease but remains at the amount of the bounty. However, the *Standard Guide to Cars and Prices* shows that almost all vehicle depreciation occurs in the first ten years of its life, so the resale value remains relatively constant afterward. Therefore, resale value of older vehicles does not change significantly from year to year before the AVRP, so this incentive is not considered.

AVRP, the number of vehicles scrapped would be determined by the difference between the new quantities supplied and demanded.

Figure 1



Assuming a drop in transaction costs for owners of the targeted vehicles however, the actual number of vehicles scrapped would be higher. At any given market price, the amount of vehicles offered for sale would increase--the supply curve would shift outward to S' and the quantity supplied would rise to $qs'(1)$ at bounty *B*. In addition, any prospective private buyer would have to compensate the seller for the reduced transaction costs offered by the AVRP in order to obtain the vehicle. In effect, transaction costs are transferred from the seller to the buyer.[8] This means that less vehicles would be demanded at any given market price--the demand curve would shift inward to D' and the quantity demanded would fall to $qd'(1)$. The total number of vehicles scrapped in response to the AVRP is then

$$\textbf{(3)}\ qs'(1) - qd'(1).$$

Figure 2 shows the results of a one-year-only AVRP or a multi-year program in its final year. In this case, any bounty above market value will create an added incentive to retire since the bounty will not be available in the next period--holding cost increases by the difference between the bounty and market value. This is shown using a new demand

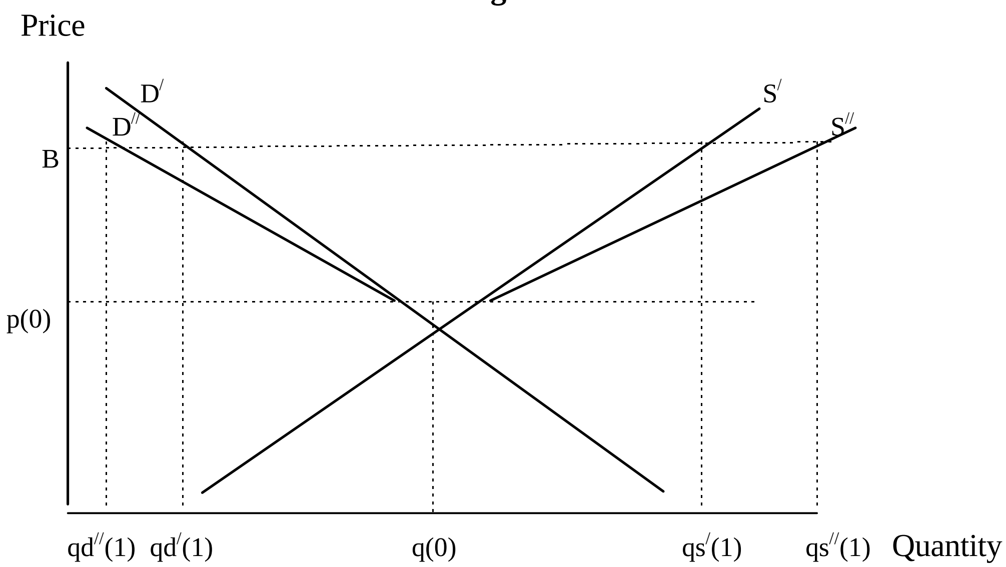
[8] For example, suppose that the only transaction cost involved in selling a vehicle is the cost of a smog check, say $50. If an AVRP offered $1,000 for a targeted vehicle the owner of such an auto (assuming the market value of the vehicle before the AVRP was less than or equal to $1,000) would only sell to a private party rather than retiring the vehicle if the prospective buyer paid $1,000 plus the cost of the smog check, or $1,050.

curve *D*" and new supply *S*" (D and S are the same as in Figure 1). The total number of vehicles retired then increases to

$$\textbf{(4)}\ qs''(1) - qd''(1).$$

It is important to note that the bounty need not be higher than the market value of a targeted vehicle to induce scrappage, due to the reduction in transaction costs. Vehicle retirement will occur as long as the bounty plus the reduction in transaction costs is higher than the market value. In Figures 1 and 2, some retirement will occur as long as the bounty is above a price corresponding to the intersection of the *S′* and *D′* curves.

Figure 2



The analysis above assumes no change in the prices of non-targeted vehicles as a result of the AVRP. The position of the demand and supply curves in the figures will depend on the prices of goods that are to some degree substitutes; that is, other used, non-targeted vehicles. Any price increase for non-targeted vehicles will raise the demand for those targeted and the result will be a rightward shift in the demand curves in Figures 1 and 2. At the same time, the supply curves for targeted vehicles will shift leftward as potential sellers of this vehicle who are planning to replace it if sold will be less likely to put their vehicle on the market in the face of higher prices for possible replacements--other used vehicles. The net effect will be fewer vehicles retired at a given bounty relative to the cases shown in Figures 1 and 2, or a higher bounty necessary to retire the same number of vehicles.

Input Assumptions

As a household's propensity to retire/sell a targeted vehicle at a given bounty will depend on the market value of the vehicle, the prices of used cars and trucks (that is, before any AVRP) represent an important input to the AVRP simulations. Data for older vehicle prices come from the *1996 Standard Guide to Cars and Prices*, which gives used light-duty vehicle prices by make, model, and series for model years 1901-1988 in 1995, supplemented by roughly 2,000 advertisements for used vehicles in various newspapers around the state. The *Standard Guide* gives prices for six different vehicle conditions: excellent, fine, very good, good, restorable, and "parts car". The fourth category (good) was chosen as the most reasonable measure of the value of the average older vehicle.[9]

For model years 1970-1988, these prices were used to estimate a weighted average price for each vehicle class in 1995, using vehicle count data from the California Department of Motor Vehicles. Newer used vehicle prices come from depreciation assumptions provided by K.G. Duleep of Energy and Environmental Analysis, Inc., who also provided both historical and projected new vehicle prices for each year in the forecast period by class. The price of a used vehicle relative to its price new is assumed to remain constant over the forecast period. For example, if in 1995 a 10 year old subcompact car is estimated to be worth one-tenth of its price new, the ratio between the two prices remains at one-tenth over 1996-2010. As an example, Table 3 below lists projected market value for various model years for all of the size classes in 2004, roughly halfway through the time period an AVRP would be operational in the South Coast.

The data in Table 3 show a number of patterns for light-duty vehicle prices that are assumed to hold for all forecast years. First, the value of a car drops quickly in the first ten to fifteen years and then begins to increase slightly. Average market value drops for late 1970's model year cars, possibly a reflection of the lower quality of these vehicles. Finally, market value begins to increase again for early 1970's cars. Vans and light-duty trucks lose their value less quickly and so remain at a higher value relative to the price of new vehicles compared to cars.

Used vehicle prices by class for a given year are also a reflection of the makes and models that make up that class. For example, subcompact and midsize cars manufactured in the early 1970's have a relatively high value, as Volkswagon Beetles make up a significant share of the former and some of the valued Detroit "muscle cars" (e.g., the Plymouth Barracuda and the Pontiac GTO) make up a large share of the latter. On the other hand, the older mini and large cars have few makes that could be considered collectors' items.

[9] GOOD is defined in the Standard Guide as, " A drivable vehicle needing no or only minor work to be functional. Also, a deteriorated restoration or a very poor amateur restoration. All components may need restoration to be "excellent" but the car is mostly useable 'as is'."

Table 3: Personal Vehicle Prices by Class for Various Model Years in 2004 (in 1995$)

Model Year	Mini Car	Subcom. Car	Compact Car	Midsize Car	Large Car	Luxury Car	Sports Car
2004	14,780	13,870	18,621	20,956	22,856	40,410	19,099
1999	5,637	5,398	7,696	7,269	7,953	18,946	7,637
1994	929	864	1,195	1,159	848	4,632	2,761
1989	907	791	1,251	1,201	1,230	5,457	3,072
1984	957	848	926	1,269	1,073	6,792	4,340
1979	830	1,239	1,119	1,655	863	5,863	4,988
1974	821	1,226	1,106	1,637	853	5,487	4,933
Model Year	**Compact Truck**	**Standard Truck**	**Compact Van**	**Standard Van**	**Compact Sport Utility**	**Standard Sport Utility**	**Mini Sport Utility**
2004	15,230	19,031	21,996	19,500	23,769	25,753	16,478
1999	6,997	9,176	10,637	9,362	11,294	12,240	7,753
1994	1,257	2,150	2,465	2,192	2,684	2,945	1,783
1989	1,543	2,354	2,545	2,522	2,854	3,309	2,024
1984	2,197	2,251	2,648	2,529	5,943	3,140	1,937
1979	2,414	1,873	2,266	2,125	4,932	2,370	2,863
1974	2,266	1,817	1,435	2,416	3,005	1,878	--*

* Class was not available in this model year.

It is important to note that the vehicle prices by class and model year used in the simulations are an estimated weighted average. In reality there is a wide variation of price within each class-model year combination due to the different makes and models within the class and the varying condition of the vehicles of each make/model. The estimates of the number and type of vehicles scrapped will therefore be less precise due to this aggregation; for example, a class-model year combination may be projected to have an average price well above the retirement bounty so that no vehicles in this grouping would be retired in a given simulation when in reality there may well be many in the class/model year whose market value will be less than the bounty. Unfortunately, data limitations do not allow for enough disaggregation of vehicle type to account for this variation. Further, even if adequate data were available, the required disaggregation would make simulation run time prohibitively high at this time. However, in spite of this limitation, the simulations should offer insights into the general patterns of vehicle retirement and replacement. CALCARS projections of vehicle stock by class and vintage for the South Coast are based on actual 1994 totals derived from Department of Motor Vehicle data. Table 4 provides the base case projections for 2004 of total personal cars and light-duty truck stock for various model years. Note that in the AVRP simulations these totals will be lower as vehicles are scrapped from 1999-2003.

Follow-up surveys conducted after demonstration scrappage programs run by Chevron and Unocal in 1993-1995 allow an estimate of the reduction in transaction costs associated with an AVRP. In each case, respondents (those who had participated in the programs) on average indicated that the lowest amount that they would have accepted to retire the vehicle was roughly $300 less than what they believed the market value of the vehicle to be.[10] This implies that transaction costs were reduced on average by this amount. Therefore, a transaction cost reduction of $300 is assumed in the simulations for vehicles targeted by the AVRP.

II. AVRP SIMULATIONS FOR THE SOUTH COAST

Two scenarios are analyzed below, an AVRP targeting ten-year and older light-duty vehicles (referred to as the 10+ program), and a program targeting twenty-year and older vehicles (20+ program). The main results are presented and discussed for each program, including estimated emission reductions, retirement percentages by vehicle age, and the effects on VMT, fuel use, and fuel economy relative to the base forecast. The cost-effectiveness and welfare impacts of the two programs are then compared. As discussed above, the retired vehicles are assumed to cause no increase in the price of other used vehicles; that is, the supply of used, non-targeted vehicles is unlimited. However, the effects of incorporating a limited supply are also discussed and an estimate made of the magnitude of maximum average price changes in 1999 for each program.

Emission reduction projections for 2009 and 2010 result from an extrapolation of the reductions in previous years. The current version of EMFAC/BURDEN includes 35 model years for cars, so by 2009, the model accounts only for vehicles as far back as 1975. However, pre-1975 vehicles are much more polluting on average than later model years. Since the CALCARS model projects a few pre-1975 vehicles still on the road in 2009 and 2010, using EMFAC/BURDEN directly for 2009 and 2010 would understate the emission reduction in these years.

[10] Woodward and McDowell, in a presentation to the California Air Resources Board on March 7, 1996.

Table 4: Personal Vehicle Stock Projections by Class for Various Model Years in 2004

Model Year	Mini Car	Subcom. Car	Compact Car	Midsize Car	Large Car	Luxury Car	Sports Car
2004	8,227	79,587	116,736	31,893	13,364	69,630	29,877
1999	9,887	94,023	121,082	36,841	15,325	71,040	30,698
1994	9,152	79,820	106,452	33,200	14,469	69,418	24,852
1989	5,379	64,585	66,101	45,102	10,263	44,487	26,352
1984	14,254	48,631	36,240	36,353	10,032	22,369	30,350
1979	15,897	8,347	2,692	22,442	8,678	12,545	20,207
1974	1,960	4,546	887	1,839	2,781	937	6,649

Model Year	Compact Truck	Standard Truck	Compact Van	Standard Van	Compact Sport Utility	Standard Sport Utility	Mini Sport Utility
2004	33,696	28,800	51,373	9,945	31,980	7,994	639
1999	32,965	24,762	53,251	8,063	27,998	6,899	572
1994	25,975	17,809	47,094	5,687	22,805	5,196	377
1989	24,511	10,470	21,498	3,437	8,228	2,532	872
1984	21,818	6,649	4,889	4,434	4,887	2,877	45
1979	7,840	6,008	694	3,732	504	539	64
1974	952	4,715	228	2,958	132	138	--*

* Class was not available in this model year.

The 10+ Program

In 1995, Sierra Research performed a study of the emission reduction potential of AVRPs in the South Coast Air Basin between 1996 and 2010. The results of the analysis showed that the scrapping of 75,000 older light-duty vehicles in each year from 1999-2010 could reduce emissions by enough to meet the M-1 SIP requirements for 2010 (25 tons per day reduction in ROG+NOx), assuming that retired vehicles were high emitters. However, targeting such vehicles presents a "moral hazard": vehicle owners may have an incentive to tamper with their auto so that it becomes eligible for the offered bounty. This analysis estimates potential emission reductions from 75,000 annual ten-year and older vehicle retirements assuming the vehicles have average (for a given model year) emission levels. At the same time, the annual bounties required to retire this number are estimated.

Sierra Research simulated scenarios for the retirement of 75,000 light-duty vehicles per year for which the retired vehicles were eight years old and older and twelve years old and older. The 10+ program scenario simulated in this paper takes the average of the two; in other words, the retired vehicles are ten years old and older. To estimate the required bounties for this level of scrappage, the dollar amounts were changed in five dollar increments until the number of vehicles retired was closest to 75,000. Therefore, the amount projected to be scrapped each year given in the results will not equal exactly 75,000.

Table 5 shows projections of the number of vehicles scrapped and replaced, the required bounties, and the estimated emission reductions. The bounty (net of administrative costs) required to retire roughly 75,000 vehicles per year would range from $785 (1995$) in the first year of the program to $995 by 2009. Between the two years, the required bounty is projected to rise as the supply of targeted vehicles is reduced and the market value of used vehicles increases (due to rising new vehicle prices over time as projected by Duleep). In 2010, the final year of the program, the required bounty would drop to $965 as the holding cost for targeted vehicles increases (as discussed in Section I). Washington (1993) estimated an administrative cost of less than $25 per vehicle[11], so a bounty of $1,000, including administrative costs, would appear to be sufficient in almost all years to allow 75,000 retirements. However, this would not be guaranteed in a limited supply case. As described in Section I, an increase in the price of used, non-targeted vehicles would mean that the bounty required for a given number of retirements would rise.

[11] These include advertising, administration, labor, emission testing (of a subsample of vehicles), and data analysis costs.

Table 5: Summary of AVRP Effects (10+ Program)

Year	Number Scrapped	Required Bounty* (95$)	Revenue Required* (1995 million$)	Number Replaced	Tons per day ROG+NOx vs. Base	Tons per day ROG+NOx M-1 SIP
1999	75,521	785	59.28	66,817	-3.48	-9
2000	74,519	805	59.99	64,455	-6.79	-9
2001	75,017	835	62.64	66,708	-9.57	-9
2002	75,190	885	66.54	66,157	-11.96	-14
2003	75,279	910	68.50	66,126	-13.85	-14
2004	75,209	930	69.94	65,691	-16.15	-14
2005	75,139	940	70.63	65,370	-17.21	-20
2006	75,116	955	71.74	65,107	-19.02	-20
2007	74,923	965	72.30	64,792	-20.11	-22
2008	75,237	980	73.73	65,086	-20.76	-22
2009	75,599	995	75.22	65,422	-21.16**	-22
2010	75,171	965	72.54	66,348	-21.36**	-25

* Net of administrative costs.
** For 2009 and 2010, emission reduction projections are an extrapolation of the reductions in previous years.

The emission reductions required by the M-1 SIP would be achieved only in 2001, 2003, and 2004. Two factors combine to give this result. First, approximately 85 percent of vehicles that would be retired in each year of the program would be replaced; if the prices of used, non-targeted vehicles were to rise, this percentage would be lower. Second, replacement vehicles would be on average newer, and therefore average VMT per vehicle would rise and the high percentage of vehicles replaced would lead to an increase in overall VMT (discussed further below). The size of the emission reduction is projected to increase at a decreasing rate over the program period as targeted vehicles on average would become less polluting. By contrast, the Sierra Research study, assuming that all retired vehicles were high emitters, estimated reductions in ROG+NOx of 24.5 tons per day in the eight-year and older scenario and 26.5 tons per day in the twelve-year and older case for 2010.

Retirement and Replacement by Vehicle Age

Table 6 shows the percentage of vehicles that would be retired by age. Vehicles of age 10-14 years would make up the largest percentage because: (1) these vehicles in most cases would be less valuable than older vintages; and (2) there would be a greater supply of these vehicles relative to older ones.

Table 6: Retirement Percentage by Vehicle Age (10+ Program)

Age	1999	2005	2010
10-14	58	45	45
15-19	23	31	28
20-24	15	12	13
25	4	12	14

Table 7 presents the percentage by age of replacement vehicles. 68 percent of replacement vehicles would be less than 10 years old in 1999; by 2010 this percentage is projected to fall to 55.5 percent. This decline can be attributed to older vehicles becoming more competitive with newer ones over the forecast period, according to the vehicle attributes supplied by K.G. Duleep. Note that replacement vehicles 10 years old and older would be those with a sufficiently high market value that retirement would not be expected.

Table 7: Replacement Percentage by Vehicle Age (10+ Program)

Age	1999	2005	2010
New	19	18	17.5
1-4	21	17	13
5-9	28	28.5	25
10-14	16.5	13.5	13.5
15-19	7	12	13.5
20	8.5	11	17.5

VMT, Fuel Use, and Fuel Efficiency

Table 8 shows the effects on VMT, gasoline use, and fuel efficiency of the 10+ program relative to the base case.

The increase in VMT, projected to reach a high of 0.47 percent in 2004, is a reflection of older vehicles being replaced with newer ones. However, in this case a younger personal vehicle fleet would not lead to higher average fuel efficiency. In effect, the price floor created by the bounty would cause a shift from vehicles with a value near or below the bounty to higher cost cars and light-duty trucks. More specifically, this would mean less ownership of low-value cars which happen to be relatively fuel efficient (e.g., mini and subcompact cars[12]) and more of higher value, less fuel efficient cars and light-duty trucks. The fuel economy effect from the change in fleet composition would dominate the effect due to the fleet being younger on average, and the result would therefore be a decline in overall fuel efficiency. This decline means that total gasoline consumption would rise by more than VMT, reaching a maximum of 0.8 percent in 2007.

Table 8: Effects of 10+ Program on VMT, Gasoline Demand, and Fuel Efficiency

Year	% Change in VMT	% Change in Gasoline Use	% Change in Fuel Efficiency
1999	+0.28	+0.34	-0.10
2000	+0.34	+0.47	-0.15
2001	+0.41	+0.60	-0.19
2002	+0.46	+0.69	-0.19
2003	+0.48	+0.75	-0.28
2004	+0.47	+0.77	-0.33
2005	+0.45	+0.78	-0.32
2006	+0.44	+0.79	-0.37
2007	+0.45	+0.80	-0.32
2008	+0.43	+0.78	-0.36
2009	+0.40	+0.76	-0.35
2010	+0.36	+0.73	-0.35

[12] During the program period, 70-75 percent of retirements are mini and subcompact cars.

The 20+ Program

In this scenario, vehicle retirement is restricted to vehicles at least twenty years old. On average, these vehicles would tend to have a higher market value than those ten to twenty years old (see Table 3), so the bounty required for a given number of retirements is higher. In addition, annual VMT per vehicle is projected to be lower for vehicles at least twenty years old compared to those ten to twenty years old.[13] These two factors by themselves would tend to reduce the cost-effectiveness of the 20+ program relative to the 10+ program. However, the emission level per mile of ROG+NOx would be higher for a targeted vehicle in the 20+ case. For example, in 1999, the average twenty-five-year old car would have almost ten times the level of ROG emissions and twice the level of NOx emissions per mile compared to a fifteen-year old car. As is shown below, this factor is projected to outweigh the first two in the simulation, so that the 20+ program would appear to be more cost-effective.

The simulation is designed to show a level of retirements that would lead to fulfilling the M-1 SIP requirements. Table 9 shows these levels, along with the projections of the bounties that would be required, the number of vehicles replaced, and the estimated reductions in tons per day of ROG+NOx.

Until 2007, retirement of roughly half of the number of vehicles scrapped in the 10+ program would be sufficient to meet the requirements of the M-1 SIP, except in the first year of the program[14]. In 2007 and beyond, the level of required retirements would reach roughly 70,000. As the table shows, the rate of increase for emission reductions would decline from 1999-2006, as the average retired vehicle becomes less and less polluting. At the same time, the difference in emissions per mile between retired and replacement vehicles (most of the retired vehicles are 20-24 years old, see Table 10) would be dropping, to the extent that a significant increase in the number of retirements would be necessary to reach 22 tons per day reduction in 2007.

[13] For example, in 1999, average annual VMT for fifteen-year and twenty-five-year old cars is projected to be 7,896 and 5,069, respectively.

[14] Staff did not attempt in the simulations to meet the M-1 SIP requirement for 1999, but rather to show directly, using the first year of the program, that it may be possible to attain more emission reductions with a smaller number of retirements.

Table 9: Summary of AVRP Effects (20+ Program)

Year	Number Scrapped	Required Bounty* (95$)	Revenue Required* (1995 million$)	Number Replaced	Tons per day ROG+NOx vs. Base	Tons per day ROG+NOx M-1 SIP
1999	37170	1170	43.49	32,760	-5.17	-9
2000	37825	1190	45.01	33,045	-10.57	-9
2001	37910	1205	45.68	33,235	-14.16	-9
2002	37986	1215	46.15	33,168	-16.58	-14
2003	37715	1225	46.20	32,846	-18.48	-14
2004	37976	1190	45.19	32,932	-19.86	-14
2005	37465	1160	43.46	32,300	-20.64	-20
2006	37979	1150	43.68	32,671	-21.2	-20
2007	69425	1575	109.34	60,190	-22.35	-22
2008	70656	1525	107.75	61,109	-24.43	-22
2009	70353	1445	101.66	60,662	-25.82**	-22
2010	70567	1240	87.50	61,276	-26.51**	-25

* Net of administrative costs.
** For 2009 and 2010, emission reduction projections are an extrapolation of the reductions in previous years.

From 2004-2006, the bounty needed to yield around 37,500 retirements is projected to drop relative to the previous year due to the large number of vehicles reaching the required age. The same pattern would occur after 2007, with the bounty in the final year reduced further because of the increase in holding cost. The percentage of scrapped vehicles would be roughly the same as in the 10+ program, around 85 percent.

Retirement and Replacement by Vehicle Age

Table 10 shows the retirement percentage by vehicle age. Most of the scrapped vehicles would come from the 20-24 age range due to the greater number of these vehicles available and their lower average market value relative to older vehicles.

Table 10: Retirement Percentage by Vehicle Age (20+ Program)

Age	1999	2005	2010
20-24	60.5	59.5	58
25-29	17	22.5	18.5
30	22.5	18	23.5

Table 11 gives the replacement percentage by vehicle age. Around 95 percent of replacement vehicles would be less than 20 years old, falling to 88 percent by 2010.

Table 11: Replacement Percentage by Vehicle Age (20+ Program)

Age	1999	2005	2010
New	16.5	15.5	11
1-4	18	14	12
5-9	24.5	24.5	23.5
10-14	25	22	25
15-19	10.5	16	16.5
20	5.5	8	12

VMT, Fuel Use, and Fuel Efficiency

Table 12 shows the effects of the 20+ program on VMT, gasoline demand, and fuel efficiency. Even with only half of the number of vehicle retirements, the increase in VMT in the 20+ program simulation is projected to be slightly higher than in the 10+ program in most years through 2006. As reflected in Tables 6 and 10, a much higher percentage of scrapped vehicles would be replaced with newer ones in the 20+ program, and the difference in annual VMT between the scrapped and replacement vehicles leads to this result. Unlike the 10+ program simulation, fuel efficiency is projected to improve in the 20+ case. This reflects the higher average age of scrapped vehicles and a lower percentage of retirements that would occur in the mini and subcompact car classes (40-60 percent in the 20+ simulation vs. 70-75 percent in the 10+ program). However, the increase in fuel efficiency would not be enough to overcome the positive effect on VMT from a younger fleet, so gasoline use would increase (although not by as much as in the 10+ case).

Table 12: Effects of 20+ Program on VMT, Gasoline Demand, and Fuel Efficiency

Year	% Change in VMT	% Change in Gasoline Use	% Change in Fuel Efficiency
1999	+0.30	+0.19	+0.10
2000	+0.39	+0.21	+0.15
2001	+0.44	+0.24	+0.19
2002	+0.47	+0.26	+0.24
2003	+0.47	+0.27	+0.19
2004	+0.46	+0.28	+0.19
2005	+0.45	+0.29	+0.14
2006	+0.45	+0.30	+0.14
2007	+0.55	+0.39	+0.18
2008	+0.61	+0.46	+0.13
2009	+0.63	+0.51	+0.13
2010	+0.64	+0.53	+0.13

Cost-Effectiveness Comparison of 10+ and 20+ Programs

Since the emissions benefits from an AVRP would continue for a few years beyond the end of the program, an estimate must be made for the benefits for 2011 and beyond. Unfortunately, the EMFAC/BURDEN model currently forecasts only through 2010. To estimate these additional benefits, staff ran CALCARS assuming vehicle retirements in 1999 and none for the next nine years. The rate of decline for emission reductions from 2000-2008 was then applied to the emissions reduction for 2010 to estimate additional annual benefits for 2011-2020. Table 13 shows these results.

Table 13: Projected Emission Reductions Beyond 2010

Year	Reduction in Tons per Day ROG+NOx 10+ Program	20+ Program
2011	19.78	23.54
2012	15.62	18.59
2013	13.06	15.54
2014	11.01	13.10
2015	9.60	11.43
2016	8.26	9.83
2017	6.85	8.15
2018	5.70	6.78
2019	4.87	5.79
2020	3.52	4.19

To estimate the cost effectiveness per ton of ROG+NOx reduced (net of administrative costs), the present value of the dollar outlay projected to be required *beginning in 1999* is divided by the total reduction in ROG+NOx estimated over 1999-2020. That is, for a given required bounty in the year 1998+i, B_i, and number of vehicles retired R_i, cost effectiveness, CE, is calculated as

$$\textbf{(5)}\quad CE = \Sigma_{i=1}^{11} B_i \times R_i/(1+d)^{i-1} / \Sigma_{i=1}^{22} T_i,$$

where d is the discount rate and T_i is the number of tons of ROG+NOx reduced in year 1998+i. Table 14 shows the estimated cost effectiveness for three discount rates.

Table 14: Comparison of Estimated Cost Effectiveness

Discount Rate (percent)	Present Value of Total Revenue Required (1995 million$)*		Cost per Ton of ROG+NOx Reduced (1995$)**	
	10+ Program	20+ Program	10+ Program	20+ Program
3	$698.10	$632.18	$6,713	$5,054
6	$600.74	$530.65	$5,777	$4,243
10	$501.91	$429.97	$4,827	$3,437

* These totals are calculated using the numerator from equation 5.

** In the 10+ program, the projected total reduction of ROG+NOx from 1999-2020 is 102,087 tons while in the 20+ program, the total is 125,087.

The 20+ program yields a projected cost per ton of ROG+NOx reduced that is 25 to 30 percent lower than in the 10+ program simulation. Thus, even with a higher outlay per retired vehicle, so many fewer vehicles would need to be scrapped for a given emission reduction in the 20+ program that it performs significantly better on a cost-effectiveness basis.

It should be noted here that total emission estimates from EMFAC(7F)/BURDEN(7F) do not include the effects from reformulated gasoline and enhanced inspection and maintenance programs that would target and remove high emitters from the personal vehicle fleet. Therefore, the emission reductions given above may be overstated. However, as discussed below, excluding price effects on non-targeted used vehicles may mean that projected emissions reductions would be understated.

Welfare and Price Impacts

As discussed earlier, a bounty offered for a particular category of vehicles effectively means a price floor--it is not likely that anyone would sell a targeted vehicle for less than the bounty, assuming the bounty is above market value. This means that prospective private buyers of targeted vehicles would pay a higher price[15], or instead buy a less preferred option. Either way, the AVRP would lead to a welfare loss for such motorists. Such a loss can be measured by the change in *consumer surplus* between a base case and one which includes an AVRP.[16] Table 15 gives the loss in total consumer surplus and

[15] The loss from a higher price is due to the increased opportunity holding cost, since all of the dollar amount paid could conceivably be recovered in the next period (if it is not the last year of the program).

[16] The concept of consumer surplus as well as the methodology for estimating consumer surplus from a choice model such as CALCARS is presented in the California Energy Commission Staff Report *1993-1994 California Transportation Energy Analysis Report*.

average per household by income group over 1999-2010 for three annual discount rates for the 10+ and 20+ programs. Note that the estimates do not include the premium above market price that many motorists would receive for a targeted vehicle, which is essentially a transfer from one population segment to another. Rather, the estimates measure the welfare effect of *market intrusion* due to an AVRP in an unlimited supply case.

Table 15: Present Value of Loss in Consumer Surplus by Income Group 1999-2010 (1995$)

		10+ Program		20+ Program	
Income Category	Discount Rate	Total Loss	Per Household	Total Loss	Per Household
$0-$20,000	3%	$11,507,138	$10.87	$22,512,256	$22.27
	6%	$9,107,382	$8.97	$18,861,216	$18.73
	10%	$7,150,649	$7.07	$15,239,826	$15.22
$20,000-$50,000	3%	$14,678,996	$8.42	$33,423,265	$19.29
	6%	$12,070,053	$6.94	$27,930,826	$16.19
	10%	$9,456,518	$5.45	$22,484,119	$13.11
$50,000-$100,000	3%	$16,391,309	$7.21	$40,727,084	$18.07
	6%	$13,506,735	$5.96	$34,297,222	$15.29
	10%	$10,614,944	$4.70	$27,900,965	$12.52
Income $100,000	3%	$1,289,819	$1.74	$3,105,952	$4.24
	6%	$1,061,050	$1.44	$2,609,499	$3.57
	10%	$831,902	$1.13	$2,116,522	$2.91

Two results are worth noting. First, the 20+ program would lead to higher losses in consumer surplus, a result due mainly to the high bounty that would be required during the last four years of the program. Second, the average loss per household would be highest for the lowest income groups. The effects would be relatively minor however: the maximum loss over 1999-2010 is projected to be $22.27 per lowest income household, or about $2 per year.

The welfare impacts given above assume no price increase for non-targeted used vehicles. That is, used vehicles from outside of the region and existing inventories at used car lots are assumed to meet the now higher demand for used non-targeted vehicles with no resulting increase in prices. However, if this were not the case, prices would have to rise to induce owners to offer additional vehicles for sale. If the price of used replacement vehicles began to rise, fewer vehicles would be offered for sale at a given bounty, so the required offer for a given number of retirements would have to increase. At the same time, used vehicles would become less competitive relative to new ones and sales of the latter would increase, the increase coming from both owners of retired vehicles that now choose a new car or truck as a replacement and owners of non-targeted used vehicles induced by the price increase to offer them for sale. The ultimate effect on the prices of used, non-targeted vehicles would depend on the elasticities of demand and supply for these vehicles, as well as the rate of substitution between new and used vehicles. Unfortunately, a full empirical analysis of price effects is beyond the scope of current modeling capabilities. In the future, such analysis will be possible using the TAMOS[17] simulator, currently being developed for the Energy Commission and the California Department of Transportation by the Institute of Transportation Studies at the University of California, which will include an equilibration mechanism for used vehicle prices.

Nevertheless, some observations can be made regarding the likely impact of allowing for price effects using the reasoning described above. First, the dollar amounts given in Tables 5 and 9 would underestimate the required bounties. Second, the ratio of new to used vehicles would increase and fewer scrapped vehicles would be replaced compared to the unlimited supply case, so the emission reductions given might be understated and the projected effects on VMT and fuel use would be overstated. Third, as both the emission reductions and the required bounties may be understated, the effect on cost-effectiveness cannot be determined. Finally, higher prices for used, non-targeted vehicles would mean more of a welfare reduction than given in Table 15.

It should be kept in mind that the effect on used vehicle prices *depends on the increase in demand relative to the number of used vehicles offered for sale in a given year, rather than total used vehicle stock*. With an idea of the transfer rate[18] for used vehicles and assumptions regarding demand elasticity[19], and assuming a linear demand in the relevant range, it is possible to estimate a range over which average price may increase as a result of a given number of retirements. The sample of approximately 5,000 households used in the estimation of CALCARS show a transfer rate of roughly 20 percent, and previous studies have shown a demand elasticity for vehicle purchase of between -0.5 and -1.0[20]. The following simplified analysis uses these estimates with projections for 1999 to estimate an average price increase range for this year.

Figure 3 shows graphically the relevant price range. Before any retirement program, the quantity of used, what will be non-targeted vehicles sold is q(0), at price p(0). With an AVRP, demand rises from D to D . With an unlimited, or perfectly elastic, supply (S_{pe}),

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[17] Stands for "Transactions/ Activity and Mobility Simulator".

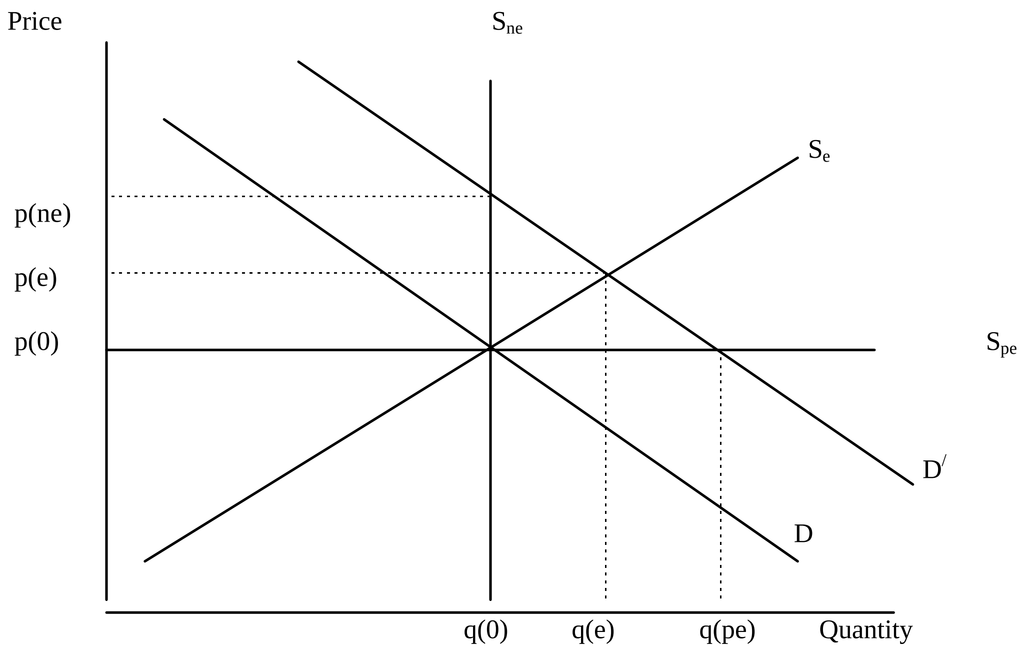
[18] The percentage of private vehicles that change ownership in a given year.

[19] Defined as the percent change in quantity demanded due to a one percent change in price.

[20] See, for example, *International Comparisons of Demand for Vehicles by Market Class*, Report by Energy and Environmental Analysis, Inc., for Oakridge National Laboratory (December, 1995).

the price of these vehicles would not increase and the new quantity sold would be q(pe). This is the assumption made in the CALCARS simulations. The maximum increase in price would occur in the case of fixed, or perfectly inelastic, supply (S_{ne}), where the price would rise to p(ne). With quantity supplied requiring a higher price for any increase (S_e), the price would rise to a level between p(0) and p(ne), p(e).

Figure 3



In 1999, the total stock of non-targeted used vehicles is projected to be 6.9 million, with a weighted average price of $6850. With a transfer rate of 20 percent, q(0) would be approximately 1.4 million. With no price increase, demand for these vehicles would rise by 53,000 in the 10+ program and by 27,000 in the 20+ case to a level corresponding to q(pe) above. Table 16 gives an estimate of p(ne), the maximum price increase, for each program for elasticities of -0.5 and -1.0.

Table 16: Estimates of Maximum Average Price Increase for Non-targeted Used Vehicles in 1999 (1995$)*

Elasticity	p(ne): Maximum Price Increase 10+ Program	20+ Program
-0.5	$506 (7.4%)	$265 (3.9%)
-1.0	$253 (3.7%)	$133 (2.0%)

*Assumes a transfer rate of 20 percent.

It must be noted again that these numbers are only intended to give a rough idea as to the magnitude of possible average price increases and represent maximums; it would be expected that actual supply will be somewhere between vertical and flat, and therefore the price increase would be less than these amounts. Nevertheless, the greater the level of vehicle retirements, the more of a shift there would be in demand and, as can be seen in Figure 3, the higher would be the price increase. Therefore, the 20+ program has an additional advantage in that it would affects non-targeted used vehicle prices to a lesser extent than the 10+ program. This means that the welfare advantage for the 10+ case shown in Table 15 may not exist without the unlimited supply assumption.

III. CONCLUSION

By using a behaviorally-based model that simulates real purchase and use decisions at the household level, this analysis represents an attempt to capture more realism in forecasts of the response of vehicle owners to an accelerated vehicle retirement program than has been possible in the past. As discussed above, the emission reduction estimates using EMFAC(7F)/BURDEN(7F) do not take into account the effects of reformulated gasoline nor enhanced inspection and maintenance programs targeting high emitters. This means that fewer high emitting vehicles may be available for retirement from 1999-2010. Therefore, the estimates of reductions in ROG+NOx are may be, all else equal, overstated. On the other hand, ignoring possible price effects in the non-targeted used vehicle market may, for a given number of retirements, lead to understated emission reduction estimates, all else equal.

In either case, there is no reason to expect that accounting for these factors would change the main result presented here, a result that suggests that *a program targeting twenty-year and older vehicles may be a more cost-effective way of reducing ROG+NOx than one targeting vehicles ten years and older*. In addition, for a given amount of emission reduction, *a 20+ program may have less of an effect on non-targeted used vehicle prices*.

There is an interesting trade-off in unlimited vs. limited supply. If a significant number of vehicles enter the South Coast from elsewhere as a result of an AVRP, and this helps hold down used car price increases in the region, total VMT and fuel use, along with the external costs that these create (e.g., congestion and noise costs) may increase, as shown in the simulations. In addition, emission reductions may be lower than without this flow of used cars. On the other hand, if this flow does not occur, consumer welfare impacts due to price effects would be more severe for a given number of vehicle retirements, especially for low-income households.

The work presented here suggests that the decision as to which vehicles will be targeted in an AVRP may have significant effects on the cost-effectiveness and welfare impacts of the program. Commission staff work will continue on accelerated vehicle retirement programs, examining other scenarios for the South Coast and their impacts.

APPENDIX: LITERATURE SURVEY

As accelerated vehicle retirement is a relatively new concept, there is a very limited amount of analysis available, particularly in academic circles. The following survey is concerned with the both the evaluation of actual programs and the limited economic analysis available for AVRPs.

In August of 1990, the American Petroleum Institute (API) published a useful discussion of AVRPs, *Reducing Emissions from Older Vehicles*, by Robert Anderson. AVRPs were presented as one of several policy options intended to reduce older vehicle emissions.[21]

In 1992, a study more focused on accelerated retirement, *Retiring Old Cars--Programs to Save Gasoline and Reduce Emissions,* was prepared by the Office of Technology Assessment at the request of the Subcommittee on Energy and Power of the House Committee on Energy and Commerce. The study concludes that a carefully designed program, targeted at areas that are out of compliance with air quality standards can achieve environmental benefits at costs equal to or lower than those of other emission-reduction options that are already in use or scheduled to be used. However, the study notes the tentative nature of its cost-benefit calculations and points out that the emission benefits from an AVRP may decline with the initiation of reformulated gasoline and the introduction of more stringent inspection and maintenance programs required by the Clean Air Act of 1990.

DRI/McGraw Hill (1991) compared estimated benefits from a 32 mile per gallon Corporate Average Fuel Economy (CAFE) standard with those of a national AVRP. The

[21] Also included in the discussion were higher registration fees, inspection and maintenance programs, cleaner fuels, new car subsidies, emission taxes, and registration restriction of older vehicles.

study found that accelerated retirement is more effective than a new CAFE in reducing emissions, assuming a bounty of $700. In addition, such an AVRP was found to be more effective at reducing fuel consumption than CAFE and provides benefits to the economy (whereas CAFE may or may not). However, the study also shows that the attractiveness of an AVRP declines over time.

The most thorough treatment of the subject so far was undertaken by the Resources for the Future (RFF). Based on the results of the 1990 demonstration AVRP in Delaware (mentioned above), the RFF study yielded three discussion papers. The first (Discussion Paper QE93-18) explores participation in an AVRP, the second (Discussion Paper 94-09) presents a supply function of emission reduction, and the third (Discussion Paper 94-27) incorporates the findings of the first two and reports conclusions for the Delaware program.[22] Using data collected from surveys of a sample of vehicle owners, both participants and non-participants in the Delaware program, the RFF study derived estimates of the participation rates at different offer prices, as well as the expected remaining life, usage, and emission levels of the retired vehicles had they remained on the road. Not surprisingly, the study found that the AVRP participation rate is very sensitive to the offer price and that the emission rate of all three regulated pollutants (hydrocarbons, carbon monoxide, and NO_x) was considerably higher in the scrapped vehicles than the average of the emission rates of all vehicles in the U.S. The authors conclude that an AVRP targeted to high emitting vehicles is likely to be quite cost effective in a limited program. However, they also caution against extending their results to large AVRPs, because large programs tend to increase the price of old vehicles in the region, and hence increase the offer price required to purchase a given number of vehicles.

Sierra Research (1995) analyzed the potential emissions benefits from a large-scale AVRP combined with an enhanced inspection and maintenance (I&M) program in the South Coast Air Basin between 1996 and 2010. Assuming various levels of light-duty vehicle scrappage per year, the study identified a few scenarios where the M-1 SIP requirements could be met for 2010. The cost-effectiveness of these programs ranged between around $7,000 and $10,000 per ton of ROG+NOx reduced, assuming a bounty of $1,000 (including administrative costs). The study does not investigate the relationship between the bounty and the number of vehicles offered for retirement nor does it offer any insights into the effect on used vehicle prices.

Washington (1993) constructed a hypothetical scrappage program for the Sacramento metropolitan region and then did a cost-benefit analysis of the program. Using the cost of achieving an equivalent emission reduction using the best available alternative control technology, Washington found the scrappage program was not justifiable on economic grounds in all scenarios considered.

[22] The first two papers were authored by Anna Alberini, Winston Harrington, and Virginia McConnell. The third is authored by the same team, with the addition of David Edelstein.

Hahn (1995) developed a scrappage supply curve for the Los Angeles region to evaluate the costs and benefits of AVRPs in this area. With this framework, the study was able to estimate an offer price at which net benefits are likely to be maximized. Hahn also shows that there is likely to be diminishing cost-effectiveness as a function of time as the supply of the worst-polluting vehicles drops and the required bounty rises.

Hsu and Sperling (1994) reviewed data from recent scrappage programs and explored the assumptions made in evaluating such programs. The authors make the point that quantifying emission reductions from an AVRP is extremely difficult due to a poor understanding of the variables that affect the outcome. These variables include the emission levels of the retired vehicle, remaining VMT of this vehicle, and the VMT and emission levels of the replacement vehicle, where there is one. The practice of using averages is shown to be an unreliable basis for predicting emission reduction, given the highly irregular distribution of emissions and VMT of the retired vehicles.

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Supplement to

Comparing the Effects of Two Accelerated Vehicle Retirement Programs Using a Behaviorally-Based Vehicle Choice Model

by

Chris Kavalec
Winardi Setiawan
Demand Analysis Office
California Energy Commission
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Introduction

The Energy Commission draft staff paper, *Comparing the Effects of Two Accelerated Vehicle Retirement Programs Using a Behaviorally-Based Vehicle Choice Model*, was mailed to various interested parties, including the California Air Resources Board (CARB) and the Western States Petroleum Association. The main suggestion for improvement was that the analysis should include the effects of the Smog Check II program when emission reductions from scrappage are estimated (the emissions inventory modeling system that was used, known as EMFAC7F/BURDEN7F, did not account for Smog Check II). Since this program targets gross polluting vehicles, it was felt that the results in the paper may have overestimated the benefits of accelerated vehicle retirement programs.

An updated emissions inventory modeling system, MVIE7G, has recently become available from CARB, designed to account for the effects of Smog Check II. Staff has recently completed a new simulation using CALCARS, the Commission's light-duty vehicle choice model, and MVIE7G. The results of this simulation are the subject of this supplement. In addition, staff offers some suggestions for the upcoming large-scale voluntary accelerated vehicle retirement program in California.

Summary of Latest Analysis of Accelerated Vehicle Scrappage by the Energy Commission

Staff has recently completed a simulation of a voluntary accelerated vehicle retirement (VAVR) program for the South Coast region, using the MVIE7G emission inventory model developed by the California Air Resources Board (CARB), which has been revised to include the effects of the Smog Check II program in California, and CALCARS, the Energy Commission's light-duty vehicle ownership, choice, and usage model. MVIE7G has been modified by Energy Commission staff to include vehicle stock, vintage distribution, and annual miles per vehicle outputs from CALCARS.

The simulated program targets vehicles 15 years of age and older and was run for two different scenarios. Scenario 1 allows replacement of retired vehicles according to the methodology of CALCARS, and the rate of replacement is around 85 percent. In this case, the decrease in average age of the light-duty fleet leads to an increase in total vehicle miles traveled (VMT). Scenario 2 constrains replacement so that total VMT remains constant compared to the base run (without VAVR). In the latter case, the replacement rate is lower, roughly 65 to 75 percent.

The results of the simulation show that as few as roughly 45,000 to 75,000 vehicles may need to be scrapped annually to meet the requirements of the M-1 SIP, as shown in Table 1 on page 4.[23] This is especially true for the constant VMT Scenario 2, where the required reduction in 2010 of ROG+NOx of 25 tons per day is achieved in 2008.

As the results here appear to cast vehicle retirement in a more favorable light than other recent analyses, Commission staff felt that it would be useful to point out and discuss the differences in methodology and input assumptions in the current study that may lead to such results. Staff urges that these differences be explored more fully before attempting to retire many more than 75,000 vehicles per year (as is now assumed) in the large-scale scrappage program beginning in 1999.

> **Emission rates of replacement vehicles.** Assuming that average per mile emissions from replacement VMT during a VAVR program equal the overall fleet average, as has been proposed by the CARB's Technical Advisory Group, may underestimate emission reductions. Table 2 on page 4 shows the replacement

[23] To achieve this level of retirement, an offer price of $1,000 from 1999-2005 and $1,200 from 2006-2010 was required in the simulation (net of administrative costs).

vehicle percentages by model year in the CALCARS simulation for 1999, projections based on actual household transactions behavior in 1993. The survey data from which CALCARS was derived showed that around 25 percent of households that replace a vehicle in a given year buy a new car or truck, although this percentage varies by level of income. The percentage shown in

Table 2 is less than 25 percent since many households replacing retired vehicles are in the lower income groups. In addition, more than 60 percent of replacement vehicles are projected to be newer than the average age of light-duty vehicles in California, 8.5 years. This means that a disproportionate amount of replacement VMT will come from new and newer vehicles and therefore per mile emissions from replacement vehicles will be lower that the overall fleet average.

Annual VMT per vehicle. VMT per vehicle by class and vintage projected by CALCARS come from a survey of roughly 5,000 households in California in 1993. Figure 1 shows the differences by model year in 1999 for cars between CALCARS projections for average annual VMT and estimates used by CARB and Sierra Research. The graph shows that VMT for older vehicles that may be scrapped is higher in the CALCARS projections, which leads to a higher emission benefit from retired autos. According to CARB documentation, VMT per vehicle estimates by model year used in MVIE7G come from 1990 and earlier Bureau of Automotive Repair data, and are held constant throughout the forecast period, so that overall average VMT per auto remains relatively constant (subject to small changes due to differences in total cars by vintage in each year). Data from CALTRANS show that average VMT per auto has risen around 900 miles from 1990-1995. Since VMT per auto by model year appears to be a critical element in determining the emissions benefit from a VAVR program, and CARB is using estimates that may understate current and future VMT per vehicle, it may be important to update such estimates.

Vintage distribution in 2010. CARB's MVIE7G model includes 35 vintages of cars in each forecast year. In the year 2009 and 2010 therefore, cars from 1974 and earlier are excluded from the analysis, although many of these vehicles may still be on the road. According to 1994 DMV records, some 600,000 pre-1975 cars are registered or unregistered for a year or less in the South Coast. Applying CARB's retention rate of 90 percent per year to these vehicles, around 100,000 of these vehicles should still be part of the fleet in 2010, about the same number as projected by CALCARS. Therefore, to the extent that these vehicles will be offered for retirement in the final two years of the forecast period, and these vehicles are non-catalyst, the emissions benefit from a retirement program will be understated in 2009 and 2010. For this reason, the estimates of emission reductions presented in Table 1 for these two years are based on an extrapolation of earlier years rather than direct use of MVIE7G. In fact, using MVIE7G for 2010 actually gives a lower tons per day emission reduction for the simulation than in 2008, even though some 120,000 older vehicles have been retired in the meantime.

Retirement eligibility. In the recent paper *Comparing the Effects of Two Accelerated Vehicle Retirement Programs Using a Behaviorally-Based Vehicle Choice Model*, staff showed that it may be more cost-effective to target an older group of vehicles (in this case, twenty-year vs. ten-year old vehicles). In addition, the March, 1995 report (no. SR95-0302) by Sierra Research showed that a program targeting twelve-year and older light-duty vehicles may be more cost-effective than one targeting those eight years and older. Staff urges the Technical Advisory Group to consider this as a possibility for further analysis before allowing the retirement of vehicles of any age.

Table 1: Simulation of VAVR Targeting Light-Duty Vehicles 15 Years of Age and Older

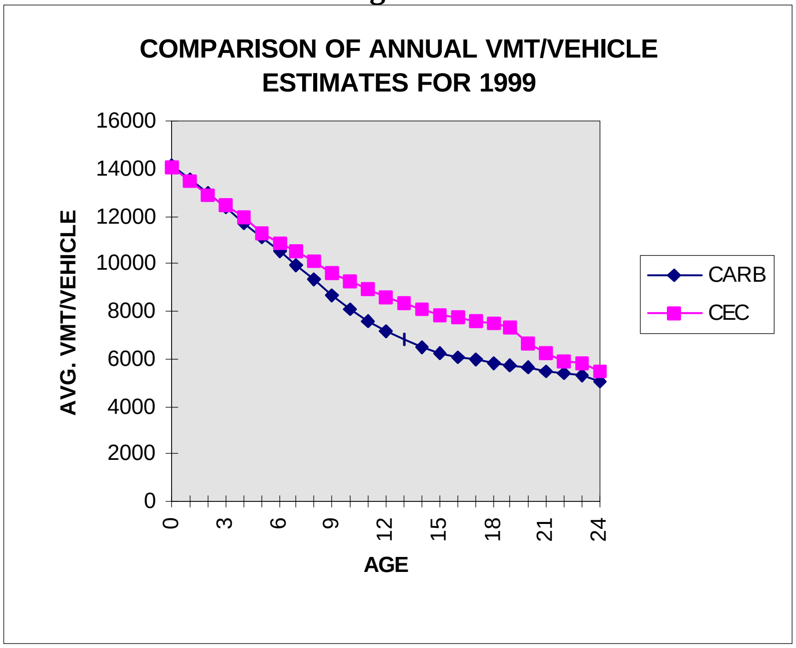
Year	Number Scrapped	Number Replaced Scenario 1[1]	Number Replaced Scenario 2[2]	Tons per day ROG+NOx vs. Base Scenario 1	Tons per day ROG+NOx vs. Base Scenario 2	Tons per day ROG+NOx M-1 SIP
1999	56,511	49,476	37,070	-5.99	-6.97	-9
2000	52,990	46,199	33,869	-10.31	-11.76	-9
2001	50,070	43,929	32,693	-13.52	-15.16	-9
2002	48,945	43,016	32,791	-15.69	-17.65	-14
2003	48,904	43,113	34,019	-17.40	-18.92	-14
2004	48,621	42,805	34,546	-18.57	-20.00	-14
2005	46,693	41,033	34,044	-19.12	-20.42	-20
2006	73,433	63,726	52,361	-21.47	-22.92	-20
2007	67,833	58,653	48,410	-23.03	-24.44	-22
2008	63,752	55,025	45,854	-23.82	-25.13	-22
2009	61,682	53,168	44,770	-24.24[3]	-25.54[3]	-22
2010	60,314	52,325	44,557	-24.44[3]	-25.74[3]	-25

[1] Unconstrained replacement of retired vehicles in CALCARS.
[2] Replacement constrained so that VMT remains the same as in the base run.
[3] For 2009 and 2010, emission reduction projections are an extrapolation of the reductions in previous years.

Table 2: Projected Replacement Percentages by Vehicle Age in 1999

New	1-5 years	6-10 years	11-15 years	>15 years
18	27	25	20	10

Figure 1



COMPARISON OF ANNUAL VMT/VEHICLE ESTIMATES FOR 1999
16000
14000
12000
10000
8000
6000
4000
2000
0
AVG. VMT/VEHICLE
0
3
6
9
12
15
18
21
24
AGE
CARB
CEC